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U.S. Nuclear Energy: National Security and Sustainability

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Through the release of atomic energy, our generation has brought into the world the most revolutionary force since prehistoric man's discovery of fire. This basic power of the universe cannot be fitted into the outmoded concept of narrow nationalisms. For there is no secret and there is no defense; there is no possibility of control except through the aroused understanding and insistence of the peoples of the world.

—Albert Einstein 1946

The words above appeared in a form letter authored by the Nobel Laureate near the end of 1946. Written under the letterhead of the Emergency Committee of Atomic Scientists (ECAS), an organization which he co-founded, Professor Einstein made an appeal to raise money to fund a "great educational task" to "carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications for society" (Einstein 1946). The aims of ECAS were "to educate the public about the dangers of atomic warfare, to promote the benign use of atomic energy, and to work for the abolition of war as the only answer to weapons of mass destruction" (Peace Pledge Union 2010).

In the more than half century since this letter was authored, the number of nations possessing nuclear weapons has risen from one to perhaps nine (Nobelprize.org 2011). In 1946, no nations possessed nuclear reactors for the generation of electricity. Reported by the World Nuclear Association (WNA), as of April 1, 2011, there are 440 commercial nuclear reactors across 30 countries operated for this purpose (WNA 2011a). Additionally, 56 countries operate approximately 250 research reactors and some 180 nuclear reactors power roughly 140 ships and submarines (WNA 2011b). While the abolition of war has not been realized, no nuclear weapons have been used in a hostile act since 1945.

A July 2010 Center for Naval Analysis (CNA) report, titled *Powering America's Economy: Energy Innovation at the Crossroads of National Security Challenges,* found that "America's energy choices are inextricably linked to national and economic security" (CNA 2010, vii). As "the most revolutionary force since prehistoric man's discovery of fire" (Einstein 1946), nuclear energy is one of these energy choices. Its sustainability affects the degree of its future impact on U.S. national security.

The motivation for this chapter is to continue the "great educational task" by examining U.S. national security and sustainability considerations of nuclear energy. As the source of 20 percent of U.S. electric energy generation, and 14 percent of worldwide electric energy generation, nuclear energy is a strategic resource on both the national and international levels (WNA 2011a). Nuclear energy is herein defined as energy produced from land-based nuclear reactors. The principal application for terrestrial nuclear reactors is the generation of electricity. Maritime or space-vehicle propulsion reactors are excluded from this definition, as are nuclear weapons. This chapter explores considerations relevant to formulating national priorities related to the future of this resource. National security interest areas of energy independence, energy security, climate change, economics, public health and safety, and nuclear terrorism and proliferation are considered. Aspects of sustainability are considered within each area. This work primarily examines domestic nuclear energy, but considers facets of foreign nuclear energy as well.

Background

On January 25, 2011, during his State of the Union Address to the nation, President Barack Obama stated:

> I challenge you to join me in setting a new goal: By 2035, 80 percent of America's electricity will come from clean energy sources. Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal, we will need them all – and I urge Democrats and Republicans to work together to make it happen (Obama 2011a).

To help meet this goal, the administration is proposing a Federal Clean Energy Standard (CES) for electricity, which is generally described in the *Economic Report of the President* transmitted to Congress in February 2011 (Obama 2011b). This CES would require the nation's electric power utilities to generate an increasing share of electricity from clean energy sources. The CES is a portion of a broader *Blueprint for a Secure Energy Future* (Obama 2011c). On March 30, 2011, the President announced the release of this *Blueprint,* which "outlines a comprehensive national energy policy, one that we've been pursuing since the day I took office" (Obama 2011d). Two tenets of the plan are cutting the nation's oil dependence by a third by 2025, and generating 80 percent of the nation's electricity from a diverse set of clean energy sources by 2035 (Obama 2011d). Nuclear energy can directly contribute to the latter, and by way of electric vehicles and plug-in hybrid electric vehicles, indirectly contribute to the former. As indicated by the degree of Presidential attention, the significance of energy to U.S. economic prosperity and national security is widely accepted. Less accepted is the path that the nation should follow to address its energy policy, as indicated by the President's urging for bipartisan support. However, there is likely no scenario that achieves the President's goal which does not include a significant role for nuclear energy.

The first commercial nuclear plant came online at Shippingport, Pennsylvania in 1957 (EIA 2011a). Today the United States has 104 nuclear reactors in operation for electrical power generation, the largest number of any country, with approximately 100 gigawatts of total generating capacity (EIA 2011a). As of 2009, these commercial reactors met 20 percent of U.S. electrical energy demand (EIA 2011a). In 2008 this represented approximately 31 percent of the worldwide nuclear generation capacity (EIA 2011a). As of April 2011, the countries with the next highest number of commercial nuclear reactors are France and Japan with 58 and 51, respectively (WNA 2011a). The countries with the highest percentage of their electricity needs supplied by nuclear energy are Lithuania with 76 percent, France with 75 percent, and Slovakia with 54 percent (WNA 2011a). At 20 percent, the United States ranks 17th (out of 30), while China, at 2 percent, ranks 30th (WNA 2011a). By one estimate, by 2035 the U.S. electricity demand is projected to increase from 2008 levels by 30 percent (EIA 2010a), and worldwide electricity generation capacity is projected to increase by 87 percent (EIA 2010b).

Before 2009, ground hadn't been broken for construction of a new nuclear power plant in the United Statesin more than three decades (Obama 2010a). The last commercial reactor added in the United States was in 1996 (TVA 2010), following 20-plus years of schedule delays and cost overruns. As of April 2011, there are 27 nuclear reactors under construction in

China, with an additional 50 planned and an additional 110 proposed (WNA 2011a). Before March 11, 2011, critics derided nuclear energy as dangerous and polluting, pointing to the Three Mile Island and Chernobyl incidents, and to radioactive waste (Greenpeace International 2010). The March 2011 earthquake and tsunami natural disasters in Japan, and the subsequent crisis at the Fukushima Daiichi power plant, have returned these concerns to the forefront of public attention. Some advocates exalt nuclear energy as a "green" solution necessary to combat global warming (Kristhof 2005). Energy is important globally, as national wealth and Gross Domestic Product (GDP) can be linked to energy use (Muller 2008, 63). With the help of Russia, Iran is in the last stages of bringing its first nuclear power plant online (Pomeroy 2010). Proliferation of nuclear materials and weapons, along with the potential for their destructive use, represent perhaps the gravest existential threat to the security of the United States (Obama 2010b, 23). Interdependencies, both supporting and conflicting, between energy, environmental, economic, security, and foreign policies are the reality.

The Nuclear Energy Strategic Environment

During a January 26, 2009, White House address, given at a time of "deepening economic crisis" (Obama 2009), with the United States engaged in open hostilities in Iraq and Afghanistan, President Obama stated: "At a time of such great challenge for America, no single issue is as fundamental to our future as energy" (Obama 2009). In his January 17, 2010, State of the Union Address, the President called for "a new generation of safe, clean nuclear power plants in this country" (Obama 2010c). Twelve days later he issued a memorandum to the Secretary of Energy, establishing a Blue Ribbon Commission on America's nuclear future. The opening paragraph of that memorandum stated:

> Expanding our Nation's capacity to generate clean nuclear energy is crucial to our ability to combat climate change, enhance energy security, and increase economic prosperity. My Administration is undertaking substantial steps to expand the safe, secure, and responsible use of nuclear energy. These efforts are critical to accomplishing many of my Administration's most significant goals (Obama 2010d).

This statement qualitatively expresses the President's desired objective for domestic nuclear energy. In his May 2010 *National Security Strategy*, the President stated "we must develop the clean energy that can power new industry, unbind us from foreign oil, and preserve our planet" (Obama 2010b, Introduction).

For more than a decade, Gallup has been querying Americans to answer the following question: "Overall do you strongly favor, somewhat favor, somewhat oppose, or strongly oppose the use of nuclear energy as one of the ways to provide electricity for the U.S.?" (Jones 2010). In each year, except 2001, favorable responses outnumbered opposing ones (Jones 2010). In an article dated March 22, 2010, Gallup reported that:

> Support has edged up in the last two years, eclipsing 60 percent this year for the first time. In addition, 28 percent of Americans now say they "strongly favor" nuclear power, also the highest Gallup has measured since the question was first asked in 1994 (Jones 2010).

In its October 2010 report, titled *The Geopolitics of Energy: Emerging Trends, Changing Landscapes, Uncertain Times*, the Center for Strategic & International Studies (CSIS) offered: "In recent years, the notion of a nuclear 'renaissance' has become fashionable as countries around the world have sought to meet burgeoning energy demand with stable, base-load, and low-carbon sources of energy" (Verrastro et al. 2010). As of April 1, 2011, there are 61 commercial nuclear reactors in construction worldwide, though only the Iranian reactor would be the first for any country (WNA 2011a).

The recent natural disasters in Japan and subsequent nuclear crisis at the Fukushima Daiichi nuclear facility have renewed fears and rallied naysayers to speak out against nuclear energy. In his March 30, 2011, *Blueprint for a Secure Energy Future* address, President Obama offered the following:

> Now, in light of the ongoing events in Japan, I want to just take a minute to talk about nuclear power. Right now, America gets about one-fifth of our electricity from nuclear energy. And it's important to recognize that nuclear energy doesn't emit carbon dioxide in the atmosphere. So those of us who are concerned about climate change, we've got to recognize that nuclear power, if it's safe, can make a significant contribution to the climate change question … we can't simply take it off the table (Obama 2011d).

Despite this showing of support by the President, the Japanese crisis will undoubtedly impact public and political support, as well as, economic considerations for nuclear power in the United States and around the world.

It is within this background and strategic environment that nuclear energy is examined. The national security interest areas of energy independence, energy security, climate change, economics, public health and safety, and nuclear terrorism and proliferation are considered. Aspects of sustainability are considered within each area.

Energy Independence

During the January 26, 2009, White House address, President Obama stated: "Today, I'm announcing the first steps on our journey toward energy independence, as we develop new energy, set new fuel efficiency standards, and address greenhouse gas (GHG) emissions" (Obama 2009). The concept of energy independence can be expressed in terms of absolute or strategic energy independence. Absolute energy independence means a country produces all of its own energy, which was largely the case in the United States prior to 1950, as reported by the American Energy Independence (AEI) website (AEI 2010). Strategic energy independence means a country allows imported energy, but only if the imported energy does not create vulnerability, such as economic, political, or military vulnerability (AEI 2010). For example, strategic energy independence might be achieved by the United States while importing petroleum from Canada and Mexico, whereas it would not be achieved when dependent on imports from the Middle East. It has been argued that U.S. energy policies under Presidents Nixon, Ford, and Carter, which were influenced by the Arab oil embargo of 1973, eventually lead to strategic energy independence for the United States during the period from 1982–1985 (AEI 2010).

Unites States oil imports declined sharply from 1980 through 1985, reaching pre-1974 levels in 1983 (EIA 2010c). While partially attributable to the opening of Alaskan oil fields, this reduction was also due to reduced oil consumption by the combination of alternative fuels, increased fuel efficiency, and conservation (AEI 2010). One such contribution came from the U.S. electrical energy sector. Electrical utilities responded to the economic and regulatory environment by replacing petroleum fuel oil with domestic coal, nuclear energy, and natural gas (AEI 2010). As a result, the United States no longer depends on petroleum to generate electricity for the power grid and since the mid-1980s has effectively achieved absolute energy independence with regard to electricity generation (AEI 2010).

Attributed largely to shifts in energy policy beginning with President Reagan (Hakes 2008, 71), the U.S. net petroleum import percentage, as a share of product supplied, increased from 27 percent in 1985 to 52 percent in 2009 (EIA 2011b). This situation was likely a factor contributing to President Obama's 2009 announcement:

> America's dependence on oil is one of the most serious threats that our nation has faced. It bankrolls dictators, pays for nuclear proliferation, and funds both sides of our struggle against terrorism. It puts the American people at the mercy of shifting gas prices, stifles innovation and sets back our ability to compete (Obama 2009).

The July 2010 CNA report summarizes:

> Economically, the nation's heavy oil dependence diverts hundreds of billions of dollars out of the econ-

omy each year and leaves American businesses and governmental agencies vulnerable to unpredictable price volatility (CNA 2010, vii).

As previously related, the electrical energy sector within the United States has effectively achieved absolute energy independence. In 2009 this sector represented 38.3 percent of U.S. energy demand (EIA 2010d). Because nuclear energy supplies this sector, and the U.S. demand for foreign petroleum is predominantly in the transportation sector, there is not a direct path for increasing overall U.S. energy independence by way of nuclear energy. In 2009 the transportation sector represented 27.0 percent of U.S. energy demand, supplied by 94 percent petroleum, 3 percent natural gas, and 3 percent renewables (EIA 2010d). There are, however, at least two plausible indirect methods by which an expanded role for nuclear energy could make a positive impact on energy independence in the transportation sector.

The first of these methods involves a greatly expanded role for vehicles that are either partially or fully energized by electricity, as is the case for plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV), respectively. The Chevrolet Volt (a PHEV) and the Nissan Leaf (an EV) are but two examples of consumer automobiles that can be powered from the electric grid. The performance of PHEV or EV vehicles is not currently adequate for replacing gasoline or diesel powered vehicles in all applications, but it is completely capable of doing so in certain applications. To reinforce this assertion, each is being offered in the U.S. market in the 2011 model year. A Chinese PHEV-60 vehicle (implying it is capable of 60 miles of electric only travel), the Build Your Dreams Auto F3DM, was the world's first production PHEV, first offered for sale to business and government buyers in China on December 15, 2008 (Balfour 2008). Like the hybrid electric vehicles (HEV) that preceded them, PHEV and EV have the potential to reduce the demand for petroleum in the transportation sector. Unlike HEV which did so solely through increased fuel economy, PHEV and EV also displace energy from petroleum with energy from the electric power grid. In the case of the U.S., this contributes to energy independence. In his 2011 State of the Union Address, President Obama called for the U.S. to "become the first country to have a million electric vehicles on the road by 2015" (Obama 2011a).

The second method involves the use of nuclear energy to produce hydrogen. Hydrogen could be used to cleanly power transportation, either by direct combustion or as a fuel for fuel cells. The term "hydrogen economy" has been widely used with regard to this concept (Rahman and Andrews 2006). There are established methods for producing hydrogen using electricity or heat to energize the processes. A clean and abundant energy source is required for such an "economy" to be viable, as the energy required to produce hydrogen is greater than the energy that is later available from it (Muller 2008, 70). Nuclear reactors could be the source of the required electricity or heat. The Department of Energy (DOE) has funded research investigating this concept (DOE 2011). In addition to the need for economically viable large-scale sources of hydrogen, there are many other practical limitations impeding a hydrogen economy, such as the physics of energy density (Muller 2008, 302) and a viable nationwide hydrogen infrastructure (Borgese 2004).

The largest contribution made by nuclear energy in terms of energy independence was its contribution to absolute energy independence in the electrical energy sector which has lasted since the mid-1980s. The significance of nuclear energy within this sector will be examined further in the section on the Climate Change. The potential for nuclear energy to impact the transportation sector, and subsequently overall U.S. energy independence, is currently marginal, though the outlook with respect to PHEV and EV is promising, especially in light of the President's recent call for one million electric vehicles on U.S. roads by 2015. The potential for a much larger impact exists should breakthroughs in complementary technology areas occur.

Sustainability Considerations

Maintaining a U.S. electric energy sector that enjoys absolute energy independence is sustainable in that the U.S. possesses ample domestic fuel reserves needed to do so and is unlikely to add additional capacity that requires foreign fuels to operate. Increasing the percentage of clean energy sources will likely add risk from the Energy Independence perspective, as reliance on considerable U.S. coal reserves will abate. Nuclear energy is the proven U.S. technology capable of reducing this risk. The United States must ensure that other forms of clean energy technology, such as solar and wind, are also available from U.S. sources, such that their increasing mix in this sector does not threaten U.S. energy independence.

Increasing U.S. energy independence in the transportation sector likely requires a paradigm shift away from petroleum. Nuclear energy indirectly offers approaches for doing so. Second order sustainability considerations, such as rare earth elements for permanent magnets in the motors of electric vehicles (or wind turbines) must be considered, along with research into electric vehicle technologies without such dependencies. Increasing U.S. energy independence is itself inherently desirable from the perspective that it reduces the many negatives mentioned: bankrolling dictators, paying for nuclear proliferation, funding terrorism, stifling innovation, setting back our ability to compete, diverting hundreds of billions of dollars out of the economy each year, and creating vulnerability to unpredictable price volatility.

The same post-1973 energy policies and statutes that resulted in sustained absolute energy independence in the electric energy sector, succeeded in re-achieving strategic energy independence in the early 1980s in the transportation sector. However this result proved temporary, as the resulting low worldwide petroleum prices rewetted the public appetite for oil and lowered the political will to stay the course. Sustainability considerations related to energy independence have proven as dependent on such public and political attitudes as on natural resources or technology alternatives. This will likely continue to be the case with regard to the future roll of nuclear energy and its ability to impact U.S. energy independence.

Energy Security

Energy security in its basest definition means having assured access to the energy resources necessary to meet demands. Energy security and independence are sometimes used interchangeably, and though interrelated, are not strictly the same. Energy security can be greatly enhanced when a nation enjoys absolute or strategic energy independence, though these situations are generally uncommon. A more recent definition of energy security is provided by the International Energy Agency (IEA) as: "the uninterrupted physical availability at a price which is affordable, while respecting environment concerns" (IEA 2011). On its webpage entitled "Energy Security," the DOE Energy Information Administration (EIA) simply lists the main headings of Oil, Natural Gas, and Electricity, with subordinate headings like: Disruptions and Vulnerabilities; Shipping, Chokepoints, and Spills; Infrastructure and Nuclear Energy (EIA 2011c). A more comprehensive definition is proposed in a United Nations (UN) Department of Economic and Social Affairs (DESA) publication as:

> A nation-state is energy secure to the degree that fuel and energy services are available to ensure: a) survival of the nation, b) protection of national welfare, and c) minimization of risks associated with supply and use of fuel and energy services. The five dimensions of energy security include energy supply, economic, technological, environmental, social and cultural, and military/security dimensions (UN DESA 2006, 151).

Nations often weight heavily their other national interests with energy security considerations in mind and employ the elements of their national power commensurately. Former Marine Corps Commandant and U.S. National Security Advisor, retired General James Jones explains:

> Our entire economy depends on the expectation that energy will be plentiful, available, and affordable. Nations like Venezuela and Iran can use oil and gas as political and economic weapons by manipulating the marketplace. Half of our trade deficit goes toward buying oil from abroad, and some of that money ends up in the hands of terrorists (AEI 2010).

With regard to nuclear energy, there are three primary energy security considerations. The first has to do with the physical security of the nuclear facilities themselves. A Brookings policy report states:

> In recent years there have been a number of terrorist plots against nuclear facilities, including the "alleged" plot by a group of Pakistani Americans to attack the Karachi nuclear reactor, initial plans by Al Qaeda to crash an aircraft into a U.S. nuclear facility, and the 2006 "Toronto 18" plot by an Islamic fundamentalist group to use a truck bomb to attack a nuclear power facility in Ontario, Canada (Banks et al. 2010, 2).

This threat is shared not only by the nuclear reactors, but also by the locations where spent nuclear fuel is maintained. The second consideration is the potential vulnerability of the power grid and the nuclear facilities to possible cyber attack. The third consideration is related to the previously mentioned concept of a worldwide nuclear "renaissance." The Brookings report cites this renaissance as posing challenges and opportunities for corporations, governments, and international organizations with regard to the nuclear fuel cycle. While noting that these issues are not new, the renewed interest by nations to acquire domestic uranium enrichment and/or reprocessing capabilities, together with a projected construction rate for nuclear reactors not seen in decades, makes these challenges significant. The Brookings report proposes that these actions might be motivated "either by perceived commercial opportunities or energy security concerns about relying on other nations for the provision of these services" (Banks et al. 2010, 2). The impact is more nuclear facilities worldwide, facing the physical and cyber security threats mentioned. With increased worldwide use of nuclear energy, especially new nuclear fuel processing/reprocessing, comes increased potential for proliferation of nuclear materials and weapons.

Sustainability Considerations

In terms of energy security there are two primary sustainability considerations. The first is related to the current costs incurred by the nation in its attempt to maintain energy security in the context of its current dependence on foreign oil and the worldwide dependence on oil from the Middle East. These costs are debatable, but are certainly considerable. Reducing these costs largely equates to reducing the dependence on foreign oil. As described, nuclear energy can indirectly contribute to that end.

Second, energy security more directly related to domestic nuclear energy involves the physical and cyber security of nuclear facilities and spent fuel storage locations. This includes susceptibility to both manmade and natural threats. The sustainability implication is not just the physical loss of nuclear capacity, as is now the case in Japan, where 4 reactors have been lost, but also the impact of such an event on public and political will, which in itself can deny the nation's optimum use of a valuable resource, as has largely been the case in the United States since the 1979 Three Mile Island incident.

Climate Change

The JOE 2010: Joint Operating Environment, produced by U.S. Joint Forces Command, states: "Climate change is included as one of the ten trends most likely to impact the Joint Force" (Mattis 2010, 32). In a 2007

CNA report, titled *National Security and the Threat of Climate Change*, the following statement is made: "Climate change can act as a threat multiplier for instability in some of the most volatile regions of the world, and it presents significant national security challenges for the United States" (CNA 2007, 1). This concept of climate change as a "threat multiplier" is echoed by the October 2010 CSIS report (Verrastro et al. 2010, 20). The CNA report further offers: "The consequences of climate change can affect the organization, training, equipping, and planning of the military services" (CNA 2007, 1). As indicated by these statements and those made by the President, climate change is certainly a pressing global matter with national security and sustainability implications.

Nuclear energy presents a contemporary paradox when it comes to environmental considerations. In the past, nuclear energy was nearly universally vilified by environmentalists due to the radioactive waste produced primarily by the fission of its nuclear fuel. In U.S. reactors this fuel is a particular isotope of uranium, called uranium-235 (U-235). When reactor grade uranium is consumed, highly radioactive byproducts, including plutonium, result. In 2005, "liberal" (Muller 2008, 154) columnist Nicholas Kristhof wrote in his New York Times opinion-editorial piece: "If there was one thing that used to be crystal clear to any environmentalist, it was that nuclear energy was the deadliest threat this planet faced" (Kristhof 2005). Kristhof went on to offer:

> But it's time for … us to drop that hostility to nuclear power. It's increasingly clear that the biggest environmental threat we face is actually global warming, and that leads to a corollary: nuclear energy is green. Nu-

clear power, in contrast with other sources, produces no greenhouse gases (Kristhof 2005).

As mentioned, nuclear energy satisfies 20 percent of the U.S. electrical energy demand. In 2009, approximately 69 percent of that demand is met by fossil fuel fired power plants, with coal being the greatest single fuel source, used to meet approximately 45 percent of the electrical energy demand (EIA 2009). While the deleterious effects of acid rain have been largely curtailed in the United States in the last 30 years (EPA 2009), the polluting byproduct of fossil fuel combustion now receiving great attention is the GHG carbon dioxide (CO_2). Burning fossil fuels releases carbon into the atmosphere that had been naturally sequestered underground. Coal combustion is the second largest source of CO_2 emitted in the United States and the single largest source on the planet (EIA 2010e).

It is with respect to combating climate change that nuclear energy could perhaps make the greatest direct impact. As previously stated, the President seeks to expand the use of nuclear energy. Since this is not quantified, the following two cases are examined. Option 1 is herein defined as substantially expanding nuclear energy capacity within the next 25 years to meet 50 percent of the U.S. electrical energy demand. Based on the EIA projected 30 percent increase in U.S. electrical energy demand, this would necessitate a fleet of 340 reactors by 2035.* Even without an expected increase in capacity from renewable sources, this option would reduce the absolute electrical energy needed from fos-

*The U.S. 2008 electrical energy requirement was 3873 billion kilowatt-hours. In the year 2035 U.S. electrical energy demand is estimated at 5021 billion kilowatt-hours. Knowing that 104 reactors provided 20% of the 2008 demand allows for a straightforward calculation of total reactors needed by 2035 for Option 1 and Option 2.

sil fuels, and subsequent CO_2 emissions, by nearly 10 percent from 2008 levels. Option 2 is herein defined as expanding the nuclear capacity only to compensate for growing demand over the next 25 years, maintaining the status quo of 20 percent of the demand met by nuclear energy. Based on projections, this would necessitate a fleet of 135 reactors. This option would not contribute to a reduction in fossil fuel use as a percentage of demand, so an absolute increase in terms of fossil fuel use and CO_2 emission would likely result. With Option 2, substantial increases in other clean energy sources would be required to slow the growth of CO_2 emission related to electrical power.

In the section on Energy Independence, the potential for nuclear reactors to energize PHEV and EV by way of the electrical power grid was discussed. Based on a report prepared at Oak Ridge National Laboratory, titled *Potential Impacts of Plug-in Hybrid Electric Vehicles on Regional Power Generation* (Hadley and Tsvetkova 2008), one may deduce that the greatly expanded use of PHEV and EV in the U.S. automobile fleet is also extremely attractive with regard to climate change considerations, but only if the energy used to power them comes predominantly from sources cleaner than today's coal. The 2009 U.S. national mixture of energy sources for electrical power is approximately 45 percent coal, 23 percent natural gas, 20 percent nuclear, 7 percent hydro, and 5 percent other renewables (EIA 2009). Drawing from the Oak Ridge report, a July 2010 article, titled "The Dirty Truth About Plug-In Hybrids" (Moyer 2010), makes a comparison between EV and PHEV relative to HEV. In a regional scenario, where the regional power grid is supplied by 84 percent natural gas and 16 percent nuclear, the notional EV carbon emission is 37 percent better than a notional HEV, while the PHEV is 20 percent better than the

HEV (gasoline consumption for the EV is reduced 100 percent relative to HEV, while the PHEV is reduced 47 percent) (Moyer 2010). In another regional scenario, where the regional power grid is supplied by 75 percent coal and 25 percent natural gas, the EV carbon emission is 36 percent worse than the HEV, while the PHEV is 12 percent worse (relative gasoline consumption same as previous case) (Moyer 2010).

By reducing the demand for petroleum, both scenarios offer significant improvements with regard to energy independence. However, only the first scenario offers an improvement with regard to GHG emissions, while GHG emissions in the second scenario are considerably worsened by adding EV and PHEV vehicles. Given this data, it is understandable that the President consistently couples climate change with energy independence, so that the latter is not optimized without consideration for the former, consistent with the two tenets of the *Blueprint for a Secure Energy Future* previously described. Given the current mix of energy sources supplying the U.S. power grid, it makes sense to replace as many non-hybrid vehicles as possible with PHEV or EV. It is also clear that to obtain the greatest reduction of GHG, reducing the percentage of coal and increasing the percentage of clean sources, such as nuclear and renewable energy sources, is necessary; though this may change if a practical clean coal technology is developed.

Despite the potential positive impact to the environment of replacing fossil fuel generated electricity with nuclear produced electricity, there are several more points to consider. Depending on the design of a nuclear plant's cooling system, large amounts of water can be required; hence nuclear plants are normally located near large readily available bodies of water.

This can be a limiting factor for certain locations, but in general is not a large impediment in the United States. Large clouds of non-polluting white steam rising from a nuclear cooling tower are an iconic image of nuclear energy to many, dramatically displaying the portion of the water cycle where liquid is returned to vapor. This design is employed where many factors dictate it to be optimal, generally meaning water is not scarce. There are other cooling designs used among the nation's 104 reactors which do not evaporate fresh water, but merely circulate it back into the large body from which it was drawn, consistent with necessary ecological considerations. Additionally, approximately 71 percent of the world's surface is covered by oceans and seas. Nuclear cooling systems are not dependent on fresh water only, and those located in coastal areas can use sea water for cooling. Given that nearly half of the world's population lives within 100 miles of the coast (Stewart 2011), nuclear reactors can often be placed where water for cooling is not in competition with water for other needs. When nuclear plants must be located farther from population centers, electricity can still be supplied, albeit with an associated cost of greater transmission line losses. The need for cooling is more a function of the heat cycle used to generate electricity, than the fuel source, meaning plants of like energy capacity will have similar water requirements whether they are nuclear or coal powered, though in the case of coal a portion of the waste heat is carried away in the polluting smoke. Unique to nuclear plants is the need to provide cooling for the fuel assembly even when the plant is not generating electricity, as residual heat from fissile fragments must be removed for safety reasons.

While nuclear energy is considered to be a clean source of energy, it is not considered to be a renewable energy source, such as hydro, solar, wind, or biomass. Nuclear energy is considered clean, because in its intended usage GHGs are not emitted into the environment (nor are other pollutants emitted). It is not considered to be a renewable energy source, because its nuclear fuel is created from a finite raw material supply, U-235 in the case of current U.S. reactors. Perhaps overlooked by Kristhof due to their relatively small contributions at the time, solar and wind are also non-CO_2 producing energy technologies. Bio-mass is generally accepted as clean in that the CO_2 released by burning bio-mass fuel is largely gas that was relatively recently removed from the atmosphere by photosynthesis. It is therefore said to be carbon neutral with no net annual increase in atmospheric CO_2 concentration. However, its combustion does release other pollutants into the atmosphere. These renewable technologies do not share the radioactive risks of nuclear energy. Despite these points, Dr. Stephen Chu, U.S. Secretary of Energy and Nobel Laureate, offers: "As a zero-carbon energy source, nuclear power must be part of our energy mix as we work toward energy independence and meeting the challenge of global warming" (Chu 2009).

Sustainability Considerations

The sustainability of burning fossil fuels has been questioned by many, not only due to the nature of the finite supply, energy independence and security considerations, but increasingly due to the emission of GHG and subsequent contribution to climate change. Nuclear energy is thus inherently sustainable with regard to physical climate change considerations. Expanding the nation's nuclear capacity to meet more than 20% of the demand in the electric energy sector could help further reduce GHG emissions.

This section also shows that while a paradigm shift to power a portion of the transportation sector with electricity via EVs or PHEVs would benefit energy independence, it could actually worsen GHG emissions in a region, unless a significant percentage of the electricity in that region is generated with fuel sources cleaner than today's coal plants. Since nuclear plant design may take advantage of a number of cooling system alternatives, the usage of large amounts of fresh water for cooling might only be chosen where this resource is not scarce. However, when nuclear plants are located in coastal areas, considerations for natural disaster events, such as tsunami, must be taken into account and mitigated. If this is not properly considered, then the public and political good will to add nuclear capacity, motivated by its benefit to combating climate change, can be negated by an incident like that currently unfolding in Japan.

Economics

When it comes to national security considerations and economics, it is generally accepted that the healthier a nation's economy, the more robust its capacity to address national security issues. Chairman of the Joint Chiefs of Staff, Admiral Mike Mullen, is credited with stating: "Our national debt is our biggest national security threat" (CNN 2010a). Relating energy, economics, and security, The *JOE* states:

> Another potential effect of an energy crunch could be a prolonged U.S. recession which could lead to

> deep cuts in defense spending (as happened during the Great Depression). Joint Force commanders could then find their capabilities diminished at the moment they may have to undertake increasingly dangerous missions (Mattis 2010, 26).

The President has identified energy as the single most fundamental issue affecting our future (Obama 2009). The President has been consistent in expressing the need for clean and sustainable energy.

The nuclear power plants making up the current U.S. fleet have been described as "cash machines" (WNA 2011c), in that they are able to produce large amounts of electricity at operating and maintenance (O&M) costs lower than fossil fuel fired plants, including coal plants. This is an attractive economic prospect, especially in light of 20-year operating license extensions which have been regularly granted by the Nuclear Regulatory Commission, beyond the initial 40 year operating license (Deutch et al. 2009, 5). These extensions have proven warranted based on the current physical condition of the nuclear plants, which exceeded the conservative estimates used in the original licensing. This same degree of quality and purposeful over-engineering have also allowed the output of the reactors to be increased during the lifetime of the plants, allowing the amount of energy supplied to U.S. consumers to increase without increasing the number of reactors (Deutch et al. 2009, 5).

Despite this situation, the economic barrier to construct additional nuclear capacity has been high, largely attributable to initial capital costs and the financing of these costs. While China is significantly expanding its nuclear energy capacity, U.S. expansion is much more modest. A major difference between nuclear energy in the United States and China is that

U.S. nuclear power plants are not nationally owned or operated, though they are very heavily regulated. Due to the fragmented nature of the U.S. electrical power generation industry, the capital cost of a new reactor can represent an unacceptable risk to an entity proposing to add new capacity. Economic risks are often too high for individual companies considering adding new nuclear capacity without mitigation assistance from the government, often in terms of loan guarantees. Historically in the 1970s and 1980s default rates on these loans were as high as 50 percent (Indiviglio 2010). Other anticipated economic risks include liability concerns, licensing delays, regulatory or statutory changes, mid-stream government mandated design changes, construction delays, and the resulting increased finance costs and delayed return on investment.

Capital costs are often estimated in terms of "overnight cost." Overnight cost "is an estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day" (EIA 2010f, 2). This concept allows financing to be treated separately and is useful for making more meaningful comparisons across technologies. In a 2009 update to an oft-cited 2003 Massachusetts Institute of Technology (MIT) study, titled *Update of the MIT 2003 Future of Nuclear Power*, the authors estimate that major U.S. construction projects, like nuclear plants, have increased 15 percent annually from 2003 through 2009 (Deutch et al. 2009, 6). Their estimate of overnight costs for additional generating capacity (2007 constant dollars) is: nuclear $4000/kW, coal $2300/kW, and natural gas $850/kW (Deutch et al. 2009, 6). For a notional 1 GW reactor the overnight capital cost would be $4 billion.

Overall competitiveness of various generating technologies is often expressed in terms of "levelized cost." Levelized cost "represents the present value of the total cost of building and operating a generating plant over an assumed economic life, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation" (EIA 2010f, 5). Levelized costs include overnight capital cost, fuel cost, and fixed and variable O&M costs. The 2009 MIT study estimate of levelized costs for additional generating capacity (2007 constant dollars) is: nuclear $0.084/kWh, coal $0.062/kWh, and natural gas $0.065/kWh (Deutch et al. 2009, 6). This study assumed a 40 year operating lifetime for the nuclear plant, not the 60 year lifetime that is becoming the U.S. norm, meaning the levelized costs for nuclear energy are likely overestimated relative to coal and natural gas.

The study also included a risk-premium in terms of a higher weighted cost of capital for the nuclear case, which was not included in the coal or natural gas case. This is due to a poor industry track record in the 1980s and 1990s, in terms of construction cost overruns, schedule delays, and loan defaults. While indications are that this premium may not be merited today, it is the opinion of the MIT authors that it should only be removed once demonstrated plausible by actual construction. As a result, many are closely watching the progress of the Vogtle nuclear project underway near Augusta, Georgia. With this risk premium removed (and still only considering a 40 year operating lifetime), nuclear levelized costs would be reduced to $0.066/kWh, which is competitive with both coal and natural gas (Deutch et al. 2009, 6). The study also includes another estimate which includes a notional $25/ton charge on the CO_2 emitted into the atmosphere. This charge does not impact the levelized cost of additional nuclear capacity, but raises the levelized cost of coal to $0.083/kWh and natural gas to $0.074/kWh (Deutch et al. 2009, 6). If one or more of these three considerations is realized (40+20 year nuclear operating license; no capital risk premium; $25/ton CO_2 emission charge), then the levelized cost for new nuclear capacity could equal or be less than that for coal or gas fired plants. The 2009 MIT study summarizes its economic analysis as:

> The 2003 report found that "In deregulated markets, nuclear power is not now cost competitive with coal and natural gas. However, plausible reductions by industry in capital cost, operation and maintenance costs and construction time could reduce the gap. Carbon emission credits, if enacted by government, can give nuclear power a cost advantage." The situation remains the same today. While the U.S. nuclear industry has continued to demonstrate improved operating performance, there remains significant uncertainty about the capital costs, and the cost of its financing, which are the main components of the cost of electricity from new nuclear plants (Deutch et al. 2009, 6).

Nuclear energy is currently the leading source of U.S. clean energy, providing more than twice the energy supplied by hydroelectric power, solar power, and wind power combined (Newell 2010). The MIT analysis is a clear indicator of the significance the inclusion of consideration for CO_2 emission can have on the economic analysis. Whether instituted in terms of a carbon tax or as a cap-and-trade program, such an initiative will change the market forces at work. The CES addresses a fundamental tenet of the *Blueprint for a Secure Energy Future*, greatly increasing the percentages of clean energy sources in the United States. The CES would essentially establish a cap-and-trade program with regard to carbon emissions for electrical power generation. The *Economic Report of the President* states:

> Electricity generators would receive credits for each megawatt-hour of clean energy generated; utilities with more credits than needed to meet the standard could sell the credits to other utilities or bank them for future use. By ensuring flexibility through a broad definition of clean energy and by allowing trading among utilities, the program is designed to meet the overall target cost-effectively. The Administration's proposal emphasizes the importance of protecting consumers and accounting for regional differences (Obama 2011b).

An analogous type of cap-and-trade system was put in place by the 1990 Clean Air Act for sulfur dioxide and nitrous oxides, which successfully achieved national goals with regard to curtailing acid rain in the United States (EPA 2009). Such a system can enable meeting the President's 2035 goal by allowing market forces to have a greater impact in picking the optimum combination of technologies and processes, as they did in the case of acid rain. However, without the Federal CES for electricity, market forces would arrive at solution that is very like the status quo or inefficiently react to a patchwork of uncoordinated state laws, hence federal government action is likely needed. To further this point, the *Economic Report of the President* offers:

> The benefits of transitioning to clean energy – energy security, cleaner air, fewer risks from climate change, and enhanced economic competitiveness—are enjoyed by everybody, not just the producers or consumers of the clean energy.…These spillovers mean that market

> rewards for switching to clean energy production are lower than the societywide benefits, market costs of switching to clean energy consumption are higher than the societywide costs, and markets alone provide less clean energy than is optimal (Obama 2011b, 127).

Arguments against a CES are generally either motivated by self-interests that would see their market share or profitability lessened by such an initiative, or by fears of unintended impacts to the U.S. economy resulting from higher U.S. energy prices. The latter is especially relevant in light of a global economy where competitors in other nations may not have to comply with similar standards. Not passing a CES, but continuing to keep it an active possibility is already having a negative impact. In an October 2010 *Fortune* online article, titled "Uncertain of Future Regulation, Businesses are Paralyzed," Dick Kelly, CEO of Xcel Energy and chairman of the Edison Electric Institute, states: "If we had a national policy and knew what the rules were, we could take action" (Colvin 2010). The article's author points out that "Kelly's industry knows only that momentous changes in the federal laws governing it are probably on the way; what those changes might be, and when they might happen, managers have no idea" (Colvin 2010). The *Blueprint for a Secure Energy Future* acknowledges this reality and offers:

> A CES will provide the signal investors need to move billions of dollars of capital off of the sidelines and into the clean energy economy, creating jobs across the country and reducing air pollution and greenhouse gas emissions (Obama 2011c, 7).

The Energy Policy Act of 2005 addressed many of the economic risks associated with the nuclear industry and provided incentives that are directly relevant to adding nuclear energy capacity. These include loan guarantees, extension of the Price-Anderson Act nuclear liability system, insurance against regulatory delays, and production tax credits. An October 2010 Congressional Research Service (CRS) report, titled *Nuclear Energy Policy*, states: "Together with higher fossil fuel prices and the possibility of greenhouse gas controls, the federal incentives for nuclear power have helped spur renewed interest by utilities and other potential reactor developers" (Holt 2010, 6). The United States has one reactor site under construction, nine additional reactors planned, and as many as 23 more proposed (WNA 2011a). An $8.5 billion loan guarantee was approved by the Department of Energy for one of these projects, and others are in progress (WNA 2011a). The CRS report also advises: "Relatively low prices for natural gas—nuclear power's chief competitor—and rising estimated nuclear plant construction costs have decreased the likelihood that new reactors would be built without federal support" (Holt 2010, 6).

Timelines and scale are important considerations as well. Putting a new nuclear reactor online in the United States has historically taken more than a decade, though Asian projects have recently been completed in less than five years (WNA 2011c). The two options discussed in the section on Climate Change projected a need for a fleet of 340 and 135 reactors by 2035 for Option 1 and Option 2, respectively. Assuming the current fleet of 104 reactors will be extended to remain operational at that time (EIA 2010a), 236 additional reactors would be needed to meet 50 percent of the projected 2035 U.S. electricity demand, and 31 additional reactors would be needed to continue to meet 20 percent. This could potentially require $985 billion in loan guarantees for Option 1 and $130 billion in loan guarantees for Option 2.** The engineering and specialized human capital needed to undertake an effort like Option 2 would likely stress the capacity of the nation, and that needed for Option 1 likely does not currently exist within the United States.

As indicated by the "cash machines" description for current nuclear capacity, and unlike fossil fueled power plants, relatively little of the cost of nuclear energy comes from the cost of the nuclear fuel itself (WNA 2011c). Once initial capital costs are met, and a nuclear reactor comes online, it produces electricity less costly than fossil fuel plants (EIA 2011d). Though a finite natural resource, uranium is abundant on the Earth, approximately as common as tin or zinc, and it is a constituent of most rocks and even of the sea water (WNA 2010). Its availability should not be a limiting consideration for nuclear energy this century (Deutch et al. 2009, 12). Unlike other fuel sources such as petroleum, nuclear energy in the United States is not subject to volatile world markets (WNA 2011c). Coal, likewise, enjoys this benefit in the United States. The United States has very large coal reserves, as do China and India (Muller 2008, 89). In 2008, China averaged adding one large (1 gigawatt sized; same output as a nuclear reactor) coal fired power plant weekly (Muller 2008, 300). In 2009, China's consump-

**A simple calculation was used to arrive at these estimates based on the February 2010 DOE loan guarantee precedent. From this precedent a new reactor requires a $4.17 billion loan guarantee ($8.33B divided by 2; FY2010 constant dollars). $4.17B x 236 reactors ≈ $985B. $4.17B x 31 reactors ≈ $130B. The amount would be distributed over the first 15-20 years of the 25 year period. Same process used for Option 2.

tion of coal exceeded three times that of the United States and is trending strongly upward (EIA 2010g). To reduce the economic motivation for the use of coal as an energy source, carbon tax and/or cap and trade programs are a possibility. Implementation of either by governments on a world-wide scale is clearly problematic. A bottom line near term result wherever either is implemented will be a higher cost of energy for consumers, commercial and private. An impact to the economies asked to absorb this will be real, but this does not mean it is not justified.

Adding new U.S. nuclear capacity will add new jobs, many of them specialized and requiring extensive education and training. Addressing this national human capital need, as part of the Energy Policy Act of 2005, in 2009 the Nuclear Regulatory Commission (NRC) "awarded nearly $20 million to 70 institutions to boost nuclear education and expand the workforce in nuclear and nuclear-related disciplines" (NRC 2009). For example, Augusta Technical College, located in Georgia near the only U.S. nuclear reactor site under construction, was awarded a $121,500 grant from the NRC "to help train the next generation of workers in the nuclear industry" (Kyzer 2010). In addition to addressing clean energy, President Obama's 2011 State of the Union Address reinforced the importance of investing in such education.

Increasing the nation's nuclear capacity could be viewed as threatening to the current U.S. coal industry. Generations of Americans have depended on the coal industry for their livelihood, with nearly 90,000 employed domestically in coal mining operations in 2009 (EIA 2010h). President Obama's 2011 State of the Union Address included the possibility of "clean coal" as part of the 80 percent clean energy source mix. Perhaps an expansion of clean energy capacity to offset growing electricity demand until such "clean coal" technologies can be developed is a possibility.

As is often the case, the direct cost of a course of action will likely determine whether it is implemented and to what degree. The costs of constructing additional nuclear energy capacity will be high. In addition to supply and demand, the economics of fossil fuel usage is dependent on what form and degree of carbon penalty that might be implemented. The true costs of climate change are extremely controversial and at best difficult to forecast. Whether the President's objective to expand nuclear energy within the United States is even capable of maintaining the 20 percent status quo remains to be seen. Based on a 2010 outlook, the DOE estimates that only six to fifteen additional nuclear reactors will come online within the United States by 2035 (EIA 2010a). If a more ambitious expansion, like that of the Option 1 scenario, is realized, then nuclear energy may make a direct impact on national security by positively impacting climate change. However, the environmental argument to incur the costs to do this is weakened if GHG reductions made by the United States are rendered moot by increases in carbon emissions from other countries. As a world leader, perhaps it is time for the United States to lead.

Sustainability Considerations

Perhaps the most pressing considerations with regard to the sustainability of nuclear energy as a strategic resource are the economics involved. While this can be said for nearly any resource, in the case of nuclear energy neither raw materials nor technology advancements are the limiting factors. Capital costs and their inherent risks of adding more capacity, driven by the size, complexity, and duration of the construction, is the principal economic driver. The largest U.S. generator of nuclear energy, Exelon (owner of Three Mile Island), did not construct any nuclear plants. They instead purchased them after they were in operation, at which point the risks associated with unknowns related to capital costs and financing were retired. The *Nuclear Energy Policy* CRS report noted the decreased likelihood that additional nuclear capacity would be built in the United States without federal support (Holt 2010, 6). Also as noted, an excerpt from the *Economic Report of the President* justifies such support for clean energy sources, which is restated here for emphasis:

> Market rewards for switching to clean energy production are lower than the societywide benefits, market costs of switching to clean energy consumption are higher than the societywide costs, and markets alone provide less clean energy than is optimal (Obama 2011b, 127).

The Energy Policy Act of 2005 addresses many of the associated economic issues, and its provisions should be sustained, both in authorities and appropriations. The scale of potential loan guarantees far surpasses those currently provided for by legislation. Sustainability of a larger scale loan guarantee program is greatly dependent on reversing the causes of loan defaults as seen previously in the United States. The CES addresses the remaining key economic consideration: a weighted economic disincentive for energy production that increases GHG levels in the environment.

Public Health and Safety

The 2010 *National Security Strategy* states: "This Administration has no greater responsibility than the safety and security of the American people" (Obama 2010b, 4). It is within this context that factors related to public health and safety implications of nuclear energy are considered.

The fear of nuclear power has been pervasive in the United States (PBS 2010), though attitudes have improved (Jones 2010). In his book *Physics for Future Presidents*, Professor Richard Muller states:

> There is great confusion not only in the minds of the public but in those of our leaders. Many people on both sides of this divisive issue think that their point of view is obvious, and that makes them suspicious of those who disagree. Nuclear power is a problem that future presidents will have to contend with, not only in making decisions, but in convincing the public that their decisions are correct (Muller 2008, 154).

The physics of a nuclear reactor are inherently similar to those of a nuclear bomb, but the engineering of a power plant and a nuclear weapon are necessarily and fundamentally different. Nuclear power plants like those used in the United States are not physically capable of exploding like a nuclear weapon. The physics of their design makes this impossible, period (Muller 2008, 159). More advanced reactor designs, such as next generation light-water reactors and pebble bed reactors, are even safer than those in use today (Muller 2008, 168). A proposed type of future reactor, called a fast breeder reactor, is fueled by plutonium and has efficiencies that make it an attractive option to some. The spent fuel from a fast breeder reactor actually contains more plutonium than the initial fuel, meaning it can be reprocessed to provide an even greater amount of future fuel. However, the physics of a fast breeder reactor design do not eliminate the possibility of a run-away reaction which could lead to a nuclear explosion (Muller 2008, 163).

Physics also shows that the radiation hazard from nuclear energy is real. The danger generally results from unintended distribution of radioactive material, as in the case of Three Mile Island or Chernobyl. The UN International Atomic Energy Agency (IAEA) estimated that there would be 4000 cancer deaths attributed to Chernobyl (UN IAEA 2005, 4), though Professor Muller believes this calculation more accurately predicts 36,000 cancer deaths (Muller 2011). Using this same calculation method, it is estimated that one cancer death may result from the Three Mile Island accident (Muller 2008, 166). Radon gas from naturally occurring uranium in the region around Three Mile Island is typically 30 percent above national average. For the 50,000 people who live in that immediate area, such natural radioactivity would lead to 60 excess cancer deaths above national averages (Muller 2008, 166). As a counterpoint, Greenpeace has estimated that the cancer deaths due to Chernobyl are closer to 100,000 (Greenpeace International 2006). Any deaths due to a preventable accident are tragic, but perhaps more tragic are deaths that result from intended usage. It has been reported that an estimated 25,000 Americans die annually due to pollutants resulting from the combustion of coal (Kristhof 2005). Additionally, today it is common for coal burning plants to bury their ash byproduct in the ground, even though these ashes are high in carcinogens (Muller 2008, 177).

Development and operation of a more suitable storage solution for spent nuclear fuel must be addressed. Today spent fuel is maintained locally at each nuclear energy facility. From a safety and security perspective, it is difficult to justify this situation. To address this issue, billions of dollars have been spent developing a centralized long term storage location at Yucca Mountain in Nevada. This project is not supported by President Obama and has seen its 2011 federal funding nearly zeroed (Tetreault 2010). Direct instructions related to this "back-end" of the nuclear fuel cycle were provided by the President to the Blue Ribbon Commission (Obama 2010d).

Sustainability Considerations

The WNA reports that as of May 29, 2011, there have been 14498 reactor-years of worldwide experience in producing civil nuclear power (WNA 2011d), and during this 50-plus year history there have been three major reactor accidents: Three Mile Island, Chernobyl, and Fukushima. The WNA summarizes: "One was contained without harm to anyone, the next involved an intense fire without provision for containment, and the third severely tested the containment, allowing minor release of radioactivity" (WNA 2011e). Based on these data, one might assert that nuclear energy has demonstrated a track record of sustainability with regard to public health and safety at appropriate risk levels, especially relative to risks associated with other means of energy production and usage. Once again public and political will are greatly, and rightly, swayed by health and safety considerations. An education and communications effort to rightly inform each is needed. An expansion of the U.S. fleet of nuclear reactors offers the ability to add safer and more efficient designs, allowing for retirement of older units and the reducing the source of harmful effects from fossil fuel combustion. A long-term, safe, secure storage solution of spent nuclear fuel seems to be a major sustainability issue that requires resolution. This will likely be a lesson learned from Fukushima.

Nuclear Terrorism and Proliferation

In his seminal 1993 paper, titled "The Clash of Civilizations?," Professor Samuel Huntington relates the response from the defense minister of India when asked what lesson he had learned from the 1991 Gulf War. The defense minister's response was: "Don't fight the United States unless you have nuclear weapons" (Huntington 1993). Professor Huntington offers that non-Western nations "have absorbed, to the full, the truth" (Huntington 1993) of this lesson.

In his opening statement within the 2010 U.S. *Nuclear Posture Review* (NPR), Defense Secretary Robert Gates states: "This NPR places the prevention of nuclear terrorism and proliferation at the top of the U.S. policy agenda" (Gates 2010, i). The NPR goes on to state:

> The most immediate and extreme threat today is nuclear terrorism. Al Qaeda and their extremist allies are seeking nuclear weapons. We must assume they would use such weapons if they managed to obtain them (Gates 2010, 3).

Preventing terrorist organizations from obtaining, creating, or employing weapons of mass destruction (WMD) has been a central theme in the on-going U.S. war against terrorism and al Qaeda. *The National Mili-*

*tary Strategy of the United States of America 2011*states: "The intersection between states, state-sponsored, and non-state adversaries is most dangerous in the area of WMD proliferation and nuclear terrorism" (Mullen 2011, 3). Additionally, preventing terrorist acts against nuclear energy infrastructure, as discussed in the section on Energy Security, are important both to directly ensure the availability of the resource and to prevent an erosion of public support for nuclear energy which could indirectly deny the resource. The NPR lists nuclear proliferation as today's next pressing threat, specifically calling out actions by North Korea and Iran:

> In pursuit of their nuclear ambitions, North Korea and Iran have violated nonproliferation obligations, defied directives of the United Nations Security Council, pursued missile delivery capabilities, and resisted international efforts to resolve through diplomatic means the crises they have created (Gates 2010, 3).

There are three key elements listed in the NPR for preventing nuclear terrorism and proliferation. The first element is most applicable to nuclear energy, while the latter two relate specifically to current nuclear weapons. The nuclear energy related element has multiple initiatives, the first of which is to "bolster the nuclear non-proliferation regime and its centerpiece, the Nuclear Non-Proliferation Treaty (NPT), by reversing the nuclear ambitions of North Korea and Iran" (Gates 2010, vi). Also identified is the need to strengthen UN IAEA safeguards and their enforcement, and to curb the illicit trade of nuclear materials and technologies. Finally, the NPR calls for "promoting the peaceful uses of nuclear energy without increasing proliferation risks" (Gates 2010, vii).

The previously cited Brookings report summarizes the proliferation risks that are currently inherent in expanded peaceful uses of nuclear energy:

> An expansion of the civilian nuclear sector to include new actors will bring with it a wider diffusion of nuclear materials, technologies, and knowledge at a time when the international regulatory regime is struggling to cope with existing security and safety concerns. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT), the foundation of international efforts to ensure nuclear non-proliferation, is facing both institutional and operational challenges with respect to current nuclear activities. Any expansion of nuclear commerce involving the spread of sensitive technologies such as uranium enrichment and spent fuel reprocessing will put additional pressure on a fragile non-proliferation regime leading to increased risks (Banks et al. 2010, vi).

Two aspects of the NPT are essentially, though perhaps unintentionally, at odds with each other. The basic intent of the NPT is to reduce the risk of nuclear war by preventing the proliferation of nuclear weapons. It also openly allows for the peaceful use of nuclear energy. The conundrum is that a nation which possesses a self-sufficient nuclear energy program, subsequently also possesses the capability to conduct a nuclear weapons program.

The two areas specifically called out in the Brookings report are uranium enrichment and spent fuel processing. Addressing the latter first, "plutonium is created in most nuclear reactors, including those built to produce electric power" (Muller 2008, 136). Professor Muller explains: "It (plutonium) comes out mixed with other nuclear waste, but it can be separated using relatively straightforward chemistry" (Muller

2008, 138). Spent fuel processing or reprocessing are terms used to describe this process. Reprocessing can be used to remove fissile waste materials from spent reactor grade uranium, so that the fuel may be used again. In this case the plutonium is a waste product. Reprocessing could also be used to recover the plutonium. In this case the plutonium recovered by reprocessing can be used as fuel for commercial nuclear reactors like those used in France. Reprocessing could be considered desirable, because in practical terms it ensures a "near-infinite" supply of nuclear fuel and it can reduce the total volume of nuclear waste produced. However, this plutonium could also be a source of nuclear material for a thermonuclear bomb. Because of this inherent risk, provisions were placed in the NPT addressing reprocessing and "developing nations that signed the NPT have agreed that they will not reprocess spent fuel" (Muller 2008, 137).

Under President G. W. Bush, the United States reversed a long-standing policy to abstain from nuclear fuel reprocessing, funding a program described as nuclear fuel "recycling" (Squassoni et al. 2008). President Obama has reversed this decision by withdrawing funding for this program before any reprocessing activity occurred. At President Obama's direction, the Blue Ribbon Commission is specifically addressing issues related to U.S. nuclear fuel reprocessing. Dr. James Acton, from the Carnegie Endowment for International Peace, addressed the Commission and spoke against domestic spent fuel reprocessing, stating: "The real value of American restraint is not that it encourages existing reprocessers to stop; it is that it doesn't encourage new ones to start" (Acton 2010). Linked to the issues of reprocessing is the need for the United States to decide on a path forward for long term storage of nuclear waste.

Uranium enrichment is not prohibited by the NPT and is a fundamental step necessary to produce reactor grade fuel like that used in U.S. commercial reactors. However, a program that is capable of enriching uranium to reactor grade is also capable of producing uranium that is weapons grade. Professor Muller explains:

> The hard part of enriching uranium is handling the large amounts you have to process to convert the uranium from 0.7 percent U-235 to reactor grade 3 percent U-235. By the time you've done that, the amount of material you have to handle has been reduced by a factor of four, and further enrichment to 80 percent or 99 percent U-235 purity is relatively straightforward (Muller 2008, 189).

As such, the NPT can too easily be used as cover for an illicit nuclear weapons program, as is potentially the case in Iran, an NPT signatory nation. The inspection authorities the treaty gives the IAEA are intended to prevent this from occurring, though this is clearly problematic as the statements from the NPR and the Brookings report have indicated.

Consistent with this line of reasoning, the supply of nuclear fuel from Russia to the Iranian nuclear reactor at Bushehr (Pomeroy 2010) could be considered a stabilizing action with regard to nuclear weapons non-proliferation. Given this supply of nuclear fuel, the on-going Iranian activities to enrich their own nuclear fuel could be considered a de-stabilizing act. The website CNN.com quoted White House Spokesman Robert Gibbs as saying:

> Russia is providing the fuel and taking the fuel back out. It, quite clearly, I think, underscores that Iran does

> not need its own enrichment capability if its intentions, as it states, are for a peaceful nuclear program (CNN 2010b).

From a physics perspective, Professor Muller offers: “No matter what the intentions of Iran are, the capability to make weapons is being developed in that country” (Muller 2008, 189).

Sustainability Considerations

The 2010 U.S. NPR effectively captures and addresses the sustainability considerations of a nuclear renaissance in terms of the potential for an increased threat of nuclear terrorism and proliferation by championing a series of initiatives: bolstering the nuclear non-proliferation regime and its centerpiece, the NPT; strengthening UN IAEA safeguards and their enforcement; and curbing the illicit trade of nuclear materials and technologies. This approach helps ensure the sustainability of commercial nuclear energy by recognizing the needs to promote the “peaceful uses of nuclear energy without increasing proliferation risks” (Gates 2010, vii). While the raw resources needed to produce nuclear fuel are not a worldwide limitation, an increasing number of nations with the capacity to turn the raw material into fuel is itself potentially threatening. A world nuclear fuel bank could alleviate the need for nuclear fuel production in additional nations (Banks et al. 2010, viii).

Recommendations

Motivated by the underpinning concept that America’s energy choices are inextricably linked to national security (CNA 2010, vii), this examination has focused on one of those energy choices: nuclear energy. From the analysis herein, I believe that all six of the national security interest areas would be advanced by: 1) substantially expanding capacity for nuclear power generation within the United States, along with 2) providing worldwide leadership to ensure that the positive contributions of "benign" nuclear energy are enjoyed and the negative aspects are mitigated. To accomplish these, the sustainability considerations discussed must be addressed. This position is consistent with the vision espoused by President Obama, though the execution of this vision must be long-term and is by no means certain. To this end, the following three recommendations are offered.

First, quantify the goal for nuclear power generation. A vision without a plan can be a difficult thing around which to create policy, commit resources, and execute a decentralized nation-wide program. President Obama's *Blueprint for a Secure Energy Future*, containing his goal of 80 percent of America's electricity coming from clean energy sources by 2035, is a good start. Given the 2009 U.S. percentage for non-fossil fuel electrical energy sources was roughly 32 percent (EIA 2009), a considerable advancement is required. An annual roadmap, by percentage and type of energy source needed to reach this 2035 goal, must be created.

A notional scenario, called Option 1 in the Climate Change and Economics sections, called for meeting 50 percent of the U.S. electricity demand with nuclear energy by 2035. This would require that other clean energy sources supply the remaining 30 percent needed to meet the President's goal. Option 1 required 236 additional nuclear reactors to be built by 2035. Today in the United States, there is new construction underway at one nuclear site. A 2010 DOE outlook, conducted prior to the *Blueprint's* release, estimated that only between six and fifteen new reactors will be built by 2035 (EIA 2010a). While these figures are estimates, and relative percentages need not be has defined in the Option 1 or 2 scenarios developed herein, clearly action must be taken very soon to address the magnitude of this disparity. Quantifying the nuclear power generation goal will allow for progress to be tracked, such that policy, resources, and execution can be adjusted accordingly, helping ensure the vision is achieved.

Second, set the stage economically to achieve the goal. Once a roadmap is in place, it must be resourced in order to be executed. Author Thomas Friedman has been quoted as using an oft-repeated Pentagon saying: "vision without resources is a hallucination" (Kotin 2008). Offering loan guarantees commensurate with the levels projected by the roadmap is a start. Addressing the causes which lead to high default rates in the past would be critical to ensuring this program succeeds. Tax incentives, to offset the large capital costs that discourage entry into the market, could later be offset by the taxes generated on revenue from the additional capacity and increased economic activity spurred by additional energy. Consistent with the 2011 State of the Union Address, a continued investment by the federal government in the human capital is needed to support the roadmap. The authorities of the 2005 Clean Energy Act address many of the relevant concerns and should be sustained and resourced.

The federal government has other means to influence resourcing beyond simply spending money from its treasury. Further streamlining the federal licensing and oversight process could pay immediate dividends in terms of time and cost savings. An example of such could be the standardizing of reactor designs to no more than two or three for a period of time, say ten years. This would allow for simplified licensing and oversight, while allowing for competition in the marketplace, and ensuring that only the safest designs are used to increase the U.S. commercial nuclear fleet. Lastly, the current stagnation on formulating energy policy regarding carbon taxes or cap-and-trade programs increases uncertainty and discourages private sector investment. The President has put forth his intent as defined in the *Blueprint for a Secure Energy Future*. Around this intent, legislation must be proposed so that the details can be debated and worked out. Perhaps an essential role of government in a capitalist society is to address areas where societal costs and benefits are not adequately reflected by market forces, but to do so to establish a balance and then allow market forces to work. Ultimately, legislation, law, and an actionable roadmap should be a priority for our nation. The roadmap will be viable only if the economics of the program are viable.

Third, with an increasing emphasis on a nuclear renaissance, the United States must remain vigilant on the world stage to ensure that existential threats to the United States and its allies are not realized through actions such as nuclear terrorism. The United States should work to gain international support for an addition to the NPT to disallow nuclear fuel enrichment by non-nuclear weapons states or by states with a nascent nuclear program, similar to how the treaty addresses nuclear fuel reprocessing. To make this feasible, another provision could create a world nuclear fuel bank (Banks et al. 2010, viii) to give those nations not producing their own fuel the energy security they require with regard to access to nuclear fuel. An economic incentive for compliance, such as subsidized lease rates for the use of the fuel, might be in the interest of the United States. Nation's with only peaceful intentions for nuclear energy would likely benefit by such provisions. Nations which refuse to accept or comply with these provisions could lose the cover to pursue an illicit nuclear weapons program that the NPT currently provides. Finally, to further address the viability of a world nuclear fuel bank and to improve upon the current public safety and energy security situations, the United States must decide and act upon a long-term storage solution for spent nuclear fuel.

Summary

This paper has endeavored to continue Professor Einstein's work to "carry to our fellow citizens an understanding of the simple facts of atomic energy and its implications to society" (Einstein 1946). In examining the relevance that nuclear energy has with regard to U.S. national security, a broad exploration of the national security interest areas of energy independence, energy security, climate change, economics, public safety, and nuclear terrorism and proliferation was conducted, along with sustainability considerations for each. From a systems perspective, it was evident that these six areas were often interrelated. Both direct and indirect ties where presented relating nuclear energy to national security. I believe that all six of the national security interest areas would be advanced by: 1) substantially expanding capacity for nuclear power generation within the United States, along with 2) providing worldwide leadership to ensure that the positive contributions of "benign" nuclear energy are enjoyed and the negative aspects are mitigated. Three recommendations for actions beneficial to implementing this position were offered.

In conclusion, the insights of a third Nobel Laureate are presented for consideration. In 2004, Professor Richard Smalley testified before the U.S. Senate Committee on Energy and Natural Resources, saying: "Energy is the single most important challenge facing humanity today.…Electricity will be the key" (Smalley 2004).

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